

# REPORT DOCUMENTATION PAGE

AFRL-SR-BL-TR-98-

Public reporting burden for this collection of information is estimated to average 1 hour per response, including gathering and maintaining the data needed, and completing and reviewing the collection of information. Send collection of information, including suggestions for reducing this burden, to Washington Headquarters Service, Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork

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1. AGENCY USE ONLY (Leave blank)		2. REPORT DATE 25 February 1998		3. REPORT TYPE AND DATES COVERED Final Technical Report, 5/1/97-12/31/97	
4. TITLE AND SUBTITLE Godunov's Method for Gas Dynamics: Current Applications and Future Development. A Symposium in Honor of S. K. Godunov				5. FUNDING NUMBERS F49620-97-1-0309	
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9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) Air Force Office of Scientific Research Major Scott Schreck, Program Manager Computational Mathematics Directorate of Mathematics and Computer Sciences Bolling AFB DC				10. SPONSORING/MONITORING AGENCY REPORT NUMBER	
11. SUPPLEMENTARY NOTES					
12a. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution unlimited.				12b. DISTRIBUTION CODE	
13. ABSTRACT (Maximum 200 words)  On May 1 and 2, 1997, an international symposium was held at the University of Michigan in honor of Sergei K. Godunov (Novosibirsk, Russia), one of the founding fathers of Computational Fluid Dynamics (CFD). Symposium chair was Bram van Leer (Aerospace Engineering). Support for the Symposium came largely from the Air Force and the National Science Foundation.  The Godunov Symposium brought together 107 CFD experts of all ages from 13 countries, including 50 students and postdocs. Three sessions of half-hour presentations by fourteen invited speakers gave an overview of the ways in which Prof. Godunov's groundbreaking work of the fifties has permeated the methodology of computing fluid flows. The subjects ranged from semiconductor modeling to the simulation of relativistic jets emitted by active galaxies. The high point of the conference was a nostalgic lecture by Prof. Godunov himself, "Recollections about Difference Schemes."					
14. SUBJECT TERMS Computational fluid dynamics Godunov-type methods				15. NUMBER OF PAGES 11	
				16. PRICE CODE	
17. SECURITY CLASSIFICATION OF REPORT unclassified	18. SECURITY CLASSIFICATION OF THIS PAGE unclassified	19. SECURITY CLASSIFICATION OF ABSTRACT unclassified	20. LIMITATION OF ABSTRACT UL		

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# Godunov's Method for Gas Dynamics: Current Applications and Future Developments

A Symposium in Honor of S. K. Godunov

Final technical report to AFOSR

regarding AFOSR Grant No. F49620-97-1-0309

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## 1 General information

This is the final technical report on the international symposium "Godunov's Method for Gas Dynamics: Current Applications and Future Developments," further referred to as the "Godunov Symposium," organized at the University of Michigan in honor of S. K. Godunov, with support from ASOFR, NSF, Journal of Computational Physics (Academic Press) and various units of the University of Michigan. The support by AFOSR was under Air Force Grant No. F49620-97-1-0309, for the period May 1 - December 31, 1997.

## 2 Occasion of the Symposium

On May 3, 1997, the Russian numerical/applied mathematician S. K. Godunov (Institute of Mathematics, Russian Academy of Sciences, Novosibirsk, Russia) received an honorary degree from the University of Michigan, for his fundamental contributions to the field of computational fluid dynamics and applied mathematics. To amplify this festive event, an international symposium was held on May 1-2, on the subject of Godunov-type numerical methods, used world-wide to compute continuum processes dominated by wave propagation. The venue of the Symposium was the François-Xavier Bagnoud (FXB) Building, home of the Department of Aerospace Engineering; Symposium Chair was Bram van Leer, from the same department.

Godunov's work of the 1950's and 1960's in the field of hyperbolic partial differential equations and their numerical approximation has had an profound effect on computational fluid dynamics. Many of today's state-of-the-art codes for simulating compressible flow, used in fields as diverse as civil aeronautics, industrial process modeling, nuclear-reactor safety, weapons research, meso-scale meteorology, planetary space physics and astrophysics, have their roots in a single paper by Godunov (1959) based on his Ph.D. thesis. In this paper the use of the solution to Riemann's initial-

value problem appears as a building block for a monotone finite-volume method for compressible flow. In extensions by later authors this concept is combined with that of non-oscillatory initial-value reconstruction, in order to achieve higher accuracy.

### 3 Purpose of the Symposium

The purpose of the Symposium was to give an overview of the current state of development and use of Godunov-type methods in science and engineering, and to offer a perspective of their future development and use. In the context of the symposium, Godunov-type methods were loosely defined as non-oscillatory finite-volume schemes that incorporate the solution (exact or approximate) to Riemann's initial-value problem, or a generalization of it. "Generalization" meant that, for example, multidimensional fluctuation splitting was included.

The symposium was technique- rather than discipline-oriented; it freely crossed interdisciplinary boundaries by demonstrating the similarity in numerical treatment of a wide range of continuum-modeling problems.

### 4 Scientific program

The scientific program of the symposium started with a full-length lecture by Phil Roe (University of Michigan) titled "Physical Reasoning in Computational Fluid Dynamics," underscoring the fundamental importance of Godunov's work in applied and numerical mathematics. In the following three sessions of half-hour lectures, invited speakers from diverse disciplines linked his work to powerful methodologies currently in use in Computational Fluid Dynamics (CFD) and other computational fields.

The material presented in turn served as the basis for three end-of-session panel discussions on "Current and Future Directions in Computational Science," lending a workshop character to the meeting.

In addition, a poster exhibit was set up for the duration of the conference.

The high point of the Symposium was a full-length lecture by Godunov himself titled "Recollections about difference schemes," an account of the earliest development of CFD in Russia, in which Godunov was personally involved. Godunov further gave lengthy comments during the panel discussions, and closed the Symposium with a thankword, in which he contrasted the present recognition of his work with the lack of appreciation he experienced throughout his career.

After the last session, tours of facilities in the College of Engineering were offered, specifically, the brand-new Media Union, home of the Center for Parallel Computing and the Visualization/Virtual Reality Lab; furthermore, the still new François-Xavier Bagnoud Building.

## 5 Participation

The symposium brought together 107 computational scientists in all stages of their career, from 13 countries. Among these were 50 students and postdoctoral researchers, of which about half were from the University of Michigan. 12 travel grants were awarded to students and postdocs from within and outside the USA, 4 to more senior scientists (including 3 Russians who otherwise would not have been able to attend). The Russian consul for science and technology in San Francisco was present and spoke during the first luncheon about US-Russian S&T relations. Worth mentioning is also the presence of two national program directors in computational mathematics: Scott Schreck, AFOSR, and Steve Davis, ARO.

## 6 Scientific impact

There was general agreement that the meeting was one of historic importance. Particularly impressive were (a) the presence of Godunov himself, one of the founding fathers of CFD, actively participating, (b) his lecture, disclosing never-heard details about the early days of CFD in Russia, and (c) the atmosphere of celebration, because of the attached honorary-degree ceremony. Add to this a sequence of invited presentations by top-notch researchers, covering the whole spectrum of computational modeling from semiconductor devices to radio galaxies, unified by a common numerical approach. Participants to the Symposium came away with a strong sense of the generality and uniform applicability of Godunov-type methods, although the limitations of the approach were also discussed, notably during the last panel discussion.

The handsome book of abstracts documents the power of Godunov-type methods and has contributed to the scientific impact of the Symposium. The book is now a collector's item; all spare copies were sold after the Symposium. Godunov's lecture, translated in English, and some more Symposium material, will appear in the *Journal of Computational Physics*.

## 7 Educational impact

Students and postdocs that were fortunate enough to attend the Symposium clearly understood they were part of a historic event. Moreover, they were presented with a top-notch scientific program which demonstrated that one computational approach can cross all discipline boundaries. This is an empowering and motivating experience: the student of computational science learns that he/she needs not feel restricted to any particular field of applications, making him/her more "marketable."

Students and postdocs were also actively involved in the program. Two graduate students and one postdoc gave half-hour presentations; in addition, one student who defended the day before the Symposium, with Godunov joining the thesis committee,

took part in the last panel discussion. There also were student contributions to the poster display.

## 8 Use of AFOSR's financial support

The financial support by AFOSR served largely to cover the travel expenses of the invited speakers and panelists; the remainder was used to pay in part for the full-color book of abstracts.

## 9 The Symposium program

Thursday 1 May

8.00-8.30am	Breakfast	
8.30-8.45	Welcoming address	Bram van Leer (UMi)
<b>Session 1</b>	<b>Basic algorithms</b>	<b>Chair Bram van Leer (UMi)</b>
8.45-9.30	Overview lecture	Phil Roe (UMi)
9.30-10.00	PPM & applications	Paul Woodward (UMn)
10.00-10.30	MUSCL & applications	Harland Glaz (UMd)
10.30-10.45	Break	
10.45-11.15	ENO & semiconductor modeling	Chi-Wang Shu (Brown)
11.15-11.45	Multi-D upwinding	Herman Deconinck (VKI, BE)
11.45-12.30pm	Algorithm development I	Panel of speakers + Rolf Jeltsch (ETHZ, CH) Rémi Abgrall (UBordeaux, FR) Paul Arminjon (U Montreal, CA)
12.30-1.30	Luncheon offered by CoE USA-Russia science relations	Valery Semin (Russian S&T Consul)

Session 2	Applications	Chair Ken Powell (UMi)
1.30-2.00pm	Modeling of heliosphere	Timur Linde (UMi)
2.00-2.30	Incompressible flow	John Bell (LLL)
2.30-3.00	Extended hydrodynamics	Clinton Groth (UMi)
3.00-3.15	Break	
3.15-3.45	CFL3D & applications	Chris Rumsey (NASA LaRC)
3.45-4.15	Astrophysics	Phil Hughes (UMi)
4.15-4.45	Moving boundaries	Sami Bayyuk (CFDRC & UMi)
4.45-5.30	Algorithm development II	Panel of speakers + Barry Koren (CWI NL) Smadar Karni (Temple)
5.30-6.30	Break/Poster viewing	
7.30-8.00	Reception hosted by CoE	

## Thursday 2 May

8.00-8.30am	Breakfast	
Session 3	Hardware/software issues	Dave Darmofal (TxA&M)
8.30-10.00am	Recollections about Difference schemes	Sergei Godunov
10.00-10.30	Break	
10.30-11.00	GASP/GUST	Bob Walters (AeroSoft)
11.00-11.30	Validation/internal flows	Charles Hirsch (VU Brussels)
11.30-12.00pm	CLAWPACK/AMRCLAW	Randy LeVeque (UWa)
12.00-12.30	Amrita & multi-fluid modeling	James Quirk (Caltech)
12.30-2.00	Luncheon offered by JCP/AP JCP-Godunov connection	Bram van Leer (UMi)
2.00-3.00	Computer architecture/software	Panel of speakers + Alain Dervieux (INRIA, FR) Tim Barth (NASA ARC) Eric Charlton (UMi)
3.00-3.10	Closing remarks	Bram van Leer (UMi)
3.10-3.30	Thankword	Sergei Godunov
3.30-4.00	Lurie carillon Recital	Ray McLellan
3.30-5.00	Tours of CoE facilities: Center for Parallel Computing & Visualization Lab Aerospace Engineering Bldg	Hal Marshall (UMi) Luis Bernal (UMi)

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